REVIEWS

Liquid Helium. By K. R. Atkins. Cambridge University Press, 1959. 312 pp. 60*s*.

Reading this book has reminded the reviewer that, although the raw material of fluid mechanics should be real fluids occurring in nature, he and many like him reserve the term 'real fluid' for fluids with a Newtonian viscosity. Good practical reasons for this narrow view of reality are easily found—two such fluids, air and water, are cheap and easily obtained, and the equations of motion are not too complicated—but it is useful to be reminded of the existence of other kinds of fluid. Much of Prof. Atkins's book is concerned with liquid helium II, which is a real fluid with most remarkable properties. It is difficult to believe that first observation of the behaviour of this liquid produced anything but bewilderment, and it is an interesting experience to read of the theoretical and experimental work that has led to a coherent account of the bulk properties of this unique liquid.

The basis of the phenomenonological theory of the properties of liquid helium II is the assumption of Tisza and of Landau that it is a mixture of two fluids, the normal component and the superfluid, which interpenetrate freely and are capable of independent movement. The normal component has an ordinary Newtonian viscosity (of order 10^{-5} poise) and carries with it all the entropy of the liquid, but the superfluid possesses neither viscosity nor entropy. The proportions of the two components varies with temperature, the fraction of the normal liquid decreasing from unity at the λ-point to zero at 0 °K. Besides accounting for the anomalous flow properties and for the thermomechanical effects that make such spectacular demonstrations, Tisza showed that the above assumption implies the existence of a second mode of sound propagation in which counterflow of the two components takes place without change of density and the discovery of this 'second sound' has placed the two-fluid theory in a very strong position.

The absence of viscosity in the superfluid might suggest that this is the perfect fluid of classical hydrodynamics but the simple experiment of rotating a beaker of liquid helium and observing the shape of the free surface shows that, unlike a perfect fluid, the superfluid is capable of taking up rotation. The explanation is that vorticity of the superfluid is concentrated in *quantized* vortex-lines of strength h/m (m is the mass of a helium atom) and that these can be generated at the walls of the container if sufficient energy is available in the flow. In the steady state, the lines are uniformly distributed through the liquid and the macroscopic appearance is that of a fluid in uniform rotation. Further evidence for the existence of quantized vortex-lines is provided by measurements of the attenuation of second-sound passing through a volume of liquid helium II in steady rotation, and by the approximate agreement between observed critical velocities of flow and the values calculated assuming that the flow can only lose energy if it has sufficient energy to form at least one vortex-line.

This leads to what is for me the most intriguing problem in the hydrodynamics of liquid helium II, the properties and nature of the turbulent flow in the superfluid. There is little doubt that flows with velocities above the critical value are in fact turbulent and that this turbulent motion is shared by the superfluid, but consideration of the mechanics of turbulent flow in a fluid with concentrated vorticity and a 'quantum' viscosity raises some new problems. A substantial beginning has been made by Vinen, who has used the technique of measuring the attenuation of second sound to study the growth and decay of vortex-lines in a turbulent flow produced by a heat current. He suggests that, when vortex-lines approach closely, they may pinch off small vortex-rings of atomic dimensions, so forming a thermal excitation (a roton) which is part of the normal liquid, and he has obtained a satisfactory description of the decay of the turbulence using results from the study of homogeneous turbulence. This is a plausible mechanism for the dissipation of the energy of the turbulent motion and, like ordinary viscosity, is most effective at destroying small-scale components of the turbulent motion. It would be an interesting problem to modify the ordinary treatment of turbulent flow in channels by taking into account the special qualities of this mode of energy dissipation and to compare the results with the observations of supercritical flow.

This is only one example of the problems which appear to require for their solution familiarity with fluid mechanics and with the structure of liquid helium, and I hope that hydrodynamicists will read this book and perhaps assist with the study of this fluid. As a very small contribution, I should like to point out that the statement on p. 191 (that flow of a normal liquid between rotating cylinders with the inner cylinder stationary cannot become turbulent at any velocity) is wrong, as was shown experimentally by G. I. Taylor (*Proc. Roy. Soc.* A, **157**, 1936, 546). The laminar flow is stable to infinitesimal axisymmetric disturbances, but there are other kinds of disturbance, one of which is apparently amplified when the Reynolds number is large.

There is much more in this book than the elucidation of the flow properties of liquid helium II, including of course discussion of the fundamental reasons why superfluidity exists in helium of mass 4 and not in other isotopes or other rare gases, but I do not feel qualified to discuss these sections. I shall only say that they, like the remainder of the book, appear comprehensive, clearly expressed and, considering the bulk of the work described, easy to read. To me at least, it has provided a most interesting introduction to this subject.

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